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The Relation of Geology to Mine Roof Conditions in the Pocahontas No. 3 Coalbed

By Noel N. Moebs and John C. Ferm

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THE RELATION OF GEOLOGY TO MINE ROOF CONDITIONS IN THE POCAHONTAS NO. 3 COALBED

by

Noel N. Moebs [1] and John C. Ferm [2]

ABSTRACT

Bureau of Mines studies of mine roof fall problems in the Pocahontas No. 3 Coalbed of southern West Virginia and southwestern Virginia have established that type and sequence of rock are significant factors in roof competence. The poorest conditions occur where the immediate roof consists of slump structures and slickensided rock. The best conditions occur where the roof consists of a sequence that coarsens upward from shale to massive sandy shale. A small manual of color photographs of rock types was devised to aid in identifying drill cores. Proper identifications should enhance the prediction of areas of potential roof problems in advance of mining.

INTRODUCTION

Virtually every mine in the Pocahontas No. 3 coalbed of southern West Virginia and southwestern Virginia (fig. 1) has experienced unanticipated roof falls of undetermined origin. The cost of these falls is high in terms of the accident rate, cleanup, and lost production.

In the interest of improved safety and efficiency in coal mining, studies were made of the geologic factors contributing to roof falls. The results, reported here, are based on work conducted under Bureau of Mines contract H0230028, through the Department of Geology, University of South Carolina,

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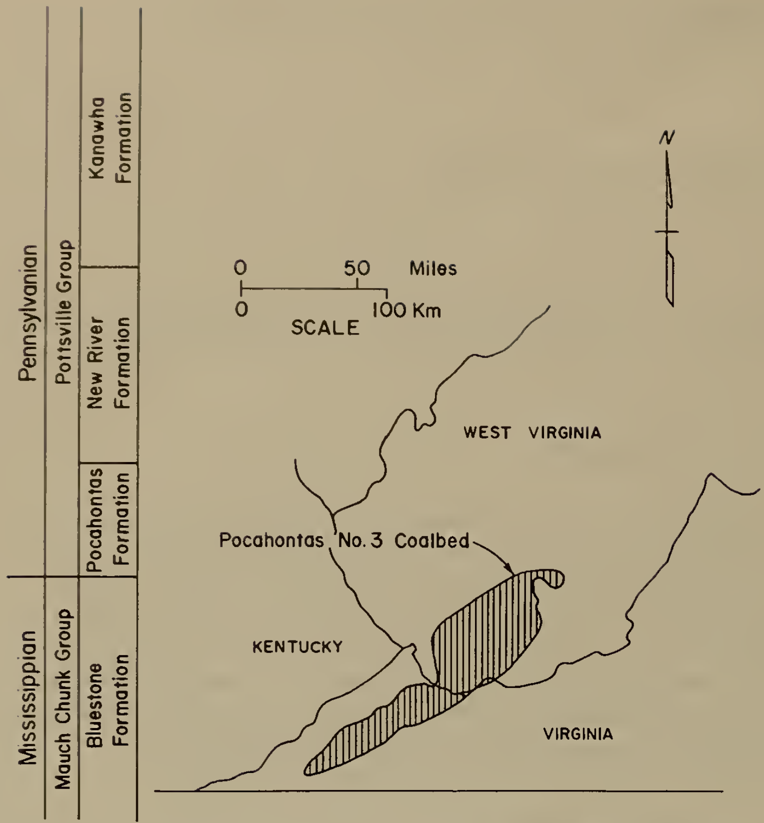

FIGURE 1. - Geographic location and generalized stratigrophic column of the Pocohontas No. 3 coalbed.

Columbia, S.C.; details of the investigations are presented in an Open File Report.[3]

The initial study began with a preliminary reconnaissance of numerous mines in the district, using a questionnaire format for systematic data collection. Statistical analysis of these data led to the selection of five large operating mines as sites for a more detailed underground investigation to determine the relation between roof quality and rock type. This investigation consisted of geologic mapping of good and bad roof areas in each of the five mines and provided an opportunity to observe great variation in rock types and roof conditions. The results clearly pointed to some obvious relationships between rocks and roof quality. However, other factors--the effects of mining methods, mine layout, the proximity of surface effects such as stream valleys, and the presence of major faults on the margin of the coalfield--could not be disregarded entirely.

As a consequence, a second study was instituted in a series of mines that were in close geographic proximity and in which mining methods were much alike. These similarities tended to negate the effects of depth of cover, major faulting, and other background attributes. In this second study, all accessible areas of the mine were examined with a standardized format for classifying

[3]Ferm, J. C., R. A. Melton, G. C. Cummins, D. Mathew, L. L. McKenna, C. Muir, and G. E. Norris. A Study of Roof Falls in Underground Mines on the Pocahontas No. 3 Seam, Southern West Virginia and Southwestern Virginia. BuMines Open File Rept. 36-80, 1978, 92 pp.; available for consultation at Bureau of Mines facilities in Tuscaloosa, Ala., Denver, Colo., Avondale, Md., Twin Cities, Minn., Rolla, Mo., Reno, Nev., Albany, Oreg., Pittsburgh, Pa., Salt Lake City, Utah, and Spokane, Wash.; U.S. Department of Energy facilities in Carbondale, Ill., and Morgantown, W. Va.; National Mine Health and Safety Academy, Beckley, W. Va.; and National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 80-158983.

both rock type and roof quality. These data did not represent the wide spectrum of rock types and roof conditions encountered in the first study, but they did provide a carefully controlled data set suitable for examining the roof competence characteristics of most common rock types. In both studies, underground mapping of roof conditions and rock properties were preceded by preparation of roof maps based on borehole data to determine the degree of precision with which roof rock types could be established in advance mining.

From the study of drill core logs in conjunction with underground mapping, it was concluded that the descriptions of rock cores provided by drilling crews were so inadequate that their potential value in prediction of roof conditions was, for the most part, lost. To improve identification of rock cores, a small field manual was prepared.[4] Copies of this prototype core manual have been distributed to selected engineers and geologists for trial use and have proven to be very useful in drill core logging.

ROOF ROCK CHARACTERISTICS AND ROOF QUALITY

In using the results of the two underground studies, factors such as mining methods, entry width, pillar arrangement, and bolting pattern are assumed to remain essentially constant. Even the best roof will fail with adverse background conditions or poor mining methods. Where roof rock types blend laterally and vertically into one another to occur in a mixed sequence, it should be remembered that two very different rock types located close together form a natural, physical discontinuity in materials and hence a zone of potential weakness.

There have been no controlled experiments to verify any of these results; as a consequence, they should be regarded primarily as a base for further experimentation or a general guide for operating personnel or engineers.

Rock Types Forming Very Poor Roof

Slump Deposits

The worst roof in the entire study occurred in slump structures where large sets of closely spaced slickensided planes extended upward for at least 30 feet into the roof, separating inclined blocks of shale, sandy shale, sandstone, fire clay, and rider coal. Slump deposits can be detected in core drilling by the presence of steeply inclined bedding separated by slickensided planes, but with 1,000- or 2,000-foot drill hole spacing, small areas (200 or

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[4]Ferm, j. C., and R. A. Melton. A Guide to Cored Rocks in the Pocahontas Basin. University of South Carolina, Columbia, S.C., 1977, 89 pp. (This manual is out of print. A revised and improved version entitled "A Guide to Cored Rocks in the Southern Appalachian Coal Fields" is available from the Department of Geology, University of Kentucky, Lexington, Ky. A manual entitled "A Guide to Cored Rocks in the Pittsburgh Basin," similar in format, was prepared under Bureau of Mines contract J018115 and is also available from the Department of Geology, University of Kentucky.)

300 feet wide) may go undetected. It is expected that slumped roof rock would be a major problem in either room-and-pillar or longwall mining.

Channel Scours

Very poor roof conditions are commonly encountered near channel scours, where fine-grained rocks abut slickensided contacts on the flanks of trough-shaped, sandstone-filled channels (roof rolls). Because such contact zones are relatively narrow (in most cases, less than 100 feet), they are not often directly encountered in drilling. However, where substantial areas show sandstone roof and the remainder is shale or some similar fine-grained rock, such a contact zone can be expected, and its general location noted. In some cases, such contacts are also characterized by slumping, and intensive advance drilling may be necessary to delineate the slump deposits.

Unless channel scours are parallel to entries, crosscuts, or longwall faces, they should present only local problems in room-and-pillar mining; however, those that extend into the coal seam may cause serious problems in longwall mining.

Fire Clays

Fire clays in the roof of the Pocahontas No. 3 Seam are uncommon. The degree to which they present roof problems is closely related to the grain size of the material and its position in the roof rock sequence. If the immediate roof consists of fine-grained fire clay, and particularly if it is crosscut by slickensides, serious roof control problems can be expected. If, on the other hand, there are 2 to 4 feet of sandy fire clay directly above the coal, roof conditions will be considerably better, but widely separated slickensided planes may result in large "horsebacks," which, once disturbed, are difficult to support.

Areas of fine-grained and sandy fire clays should be detectable with drilling on 1,000- or 1,500-foot spacing. However, careful mapping to show their exact position relative to the top of the coal should be done as mining into such areas progresses. Careful monitoring should indicate in advance the presence of clay directly over the coal and allow for planning additional support.

Fire clays are considered very poor top for both longwall and room-and-pillar mining, but sandy fire clay may have some advantages in longwall mining as it should fall readily behind the supports.

Kettlebottoms

A kettlebottom is a cylindrical or inverted funnel-shaped rock mass imbedded in the coal mine roof rock. It consists of an erect or sloping mold of an ancient tree stump or root system. The margins of a kettlebottom are nearly always slickensided or marked by a thin layer of coaly material.

Kettlebottoms are included in the very-poor-roof category although they are very small, local features of erratic occurrence, which cannot be detected by core drilling. When they are encountered during mining, the risk from falls can be reduced by inserting a diagonal bolt through the kettlebottom into the enclosing rock.

Rock Types Forming Poor-to-Fair Roof

Crossbedded and Pebbly Sandstone

Many sandstones that are strongly crossbedded or contain zones of shale, ironstone or coal pebbles, or coal streaks produce weak roof. Such zones generally occur in the lower part of sandstone units but are very erratically distributed, and their occurrence is not readily predicted by advance core drilling or detailed underground mapping. Room-and-pillar mining is more adversely affected by these rocks than longwall mining. In longwall mining, features such as pronounced crossbedding, pebbles or streaks of shale, coal, and ironstone enhance breakup characteristics and facilitate caving.

Sandstone With Shale Streaks and Interbedded Shale and Sandstone

These rocks, which consist of hard, durable sandstone interlayed with relatively weak shale, produce poor roof (called stackrock), and rocks with close spacing of soft, thick shale layers seem to be the most troublesome. Where interbedded shale and sandstone rocks are present, they are relatively widespread and can be detected by advance core drilling. Such rocks were observed only in room-and-pillar mining in the area studied, but favorable behavior can be anticipated in longwall mining where prompt caving is desired.

Crystallized Sandstone and Conglomerate

Roof rocks of this type were observed in the Pocahontas No. 3 Seam only in northern Buchanan County, Va., but their presence can be expected both north and west of this location. They are generally widespread, and core drilling on 1,000-foot spacing combined with ongoing underground mapping should clearly delineate their occurrence. These rocks are extremely hard and brittle and tend to break abruptly. Roof bolting is costly and time consuming because drilling bolt holes is very slow and requires frequent changing of bits. Moreover, there is some question as to whether the bolt holes weaken the rock more than the bolts strengthen it. The most serious problem with crystallized sandstone and conglomerate occurs in longwall mining when the caving behind the supports simultaneously releases methane and generates sparks as broken rock fragments collide. In the Buchanan County area, this problem has created ignitions resulting in serious delays in production.

Rock Types Forming Good Roof

Massive Gray Sandstone

This rock type is a very common roof material over the Pocahontas No. 3 Coalbed, and where it does not include pronounced crossbeds, shale or coal streaks, or shale or ironstone pebbles, it produces an excellent roof material. It forms a good top in room-and-pillar mining, but in longwall mining there is some tendency for the rock not to fall behind the supports. The presence of massive sandstone can be mapped using 1,500-foot drill hole spacing, but during mining, the presence of areas of shale, coal, or ironstone pebbles and streaks should be monitored.

Massive Sandy Shale

This rock type--a dark-gray shale that is gritty to the touch but without abundant sand streaks--makes up the best roof observed in the study area. In many cases, it occurs in a 15- to 20-foot sequence that begins with a thin, soft, dark-gray shale lying directly over the coal and grades upward into sandy shale. Such sequences are apparently very widespread, and reasonably accurate maps of their distribution can be prepared using corehole data. Relatively few problems have been encountered in either room-and-pillar or longwall mining in the mines studied.

Other roof rock types have been found in Pocahontas No. 3 mines, but their occurrence is too infrequent to permit general conclusions concerning them.

ROCK CORE PHOTO MANUAL

One of the first characteristics of core log data that became apparent in the course of the underground studies was that, in general, the written log descriptions indicated in only an approximate way the variety of rocks actually encountered, and many details relevant to roof behavior were omitted. Discussions with drilling and engineering personnel and observations of logging procedures indicated that many core loggers were concious of differences between rocks but lacked sufficient vocabularly to describe their observations. Adding technical terminology without a fundamental understanding of its meaning only seemed to add to the confusion.

To increase the precision of core logging procedures, a manual was prepared, consisting of color photographs of the common rock types, together with names and code numbers that could be used to describe them (fig. 2). For the more abundant types, several examples were shown, and a simple key was provided to assist in identification. In addition, data sheets were prepared so that notetaking could consist simply of recording a numeric code for rock types and any comments indicating special features or modifications of terms and thicknesses of the rock types. Computer programs accepted these data for storage and retrieval and permitted conventional drillers' reports to be retrieved in printout form or graphic portrayal of the log. Details of the

FIGURE 2. - Rock core photo manual.

computer system are presented by Ferm.[5] This method of notetaking and recording data is now in use by several major coal companies and has made easier the task of determining the lateral distribution of rock types believed to be associated with bad roof conditions.

CONCLUSIONS

Studies of mines in the Pocahontas No. 3 Coalbed showed a relationship between geologic structure and mine roof quality. Slump deposits, channel scours, fine-grained fire clays, and kettlebottoms were found to be constituents of very poor roof. Crossbedded and pebbly sandstone, interbedded shale and sandstone, and crystallized sandstone and conglomerate are poor-to-fair roof materials. Massive gray sandstone produces a good roof, and a rock sequence grading upward from shale to massive sandy shale makes up the best roof observed in these studies.

Potential roof problems may be predicted in advance of mining, through drilling and identification of the rock cores. Although small or erratic features may be missed, most rock types are widespread enough to be detected by core drilling on 1,000-foot drill hole spacing.

To make identification of the rock cores more precise and uniform, a small manual of color photographs of rock types and a simplified system of notetaking were prepared. The information obtained through this system can be used to designate potentially hazardous areas that will require extreme caution, supplementary roof support, deferred mining, or special extraction methods. The preliminary maps can be supplemented by monitoring of roof conditions as mining progresses.

Such a system of preliminary mapping followed by monitoring should result in the improved application of geologic methods to coal mine ground control and greatly increase safety and efficiency in underground mining.

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[5]Ferm, J. C., and J. T. Berger. A Computer Graphics System Preparing Coal Bore Hole Data for Mapping. Computer Graphics, v. 2, No. 8, September 1979, pp. 20-26.
Hedge, S., J. T. Berger, and J. C. Ferm. An Interactive Computer System Preparing Borehole Data for Coal Seam Mapping. Trans. AIME, v. 268, 1980, 11 pp.

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